ESTIMATES OF SURVIVAL AND CONDITION OF JUVENILE SALMONIDS PASSING THROUGH THE DOWNSTREAM MIGRANT FISH PROTECTION FACILITIES AT RED BLUFF DIVERSION DAM ON THE SACRAMENTO RIVER, SPRING AND SUMMER 1994

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Estimates of Survival and Condition of Juvenile Salmonids Passing Through the Downstream Migrant Fish Protection Facilities at Red Bluff Diversion Dam on the Sacramento River, Spring and Summer 1994

Annual Report

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Abstract.—Comparisons were made of survival between fingerling chinook salmon *Oncorhynchus tshawytscha* (fish) which passed through the bypass facility at Red Bluff Diversion Dam (treatments) and fish which did not (controls). No direct mortality occurred in recaptured treatment fish (N=5,253). Survival 3 d after treatment was high at 99.4%. There was no significant difference in survival between treatment and control groups 3 d after trials. Significant differences (P=0.049) in survival 7 d after trials were inconsistent, with higher treatment survival (92.8%) than control groups (91.8%). Many treatment fish (40%) were not sampled for survival due to passage delays. Descaling and other injuries incurred by treatment groups which passed through the bypass in less than 9 min, and late-treatment groups that remained in the bypass from 10 to 15 min were compared to descaling and other injuries incurred by control groups. Descaling was low (< 8%, mean) in all treatments. There was no significant difference in descaling between treatment and control groups, or between late treatment and control groups. Fish with one or more injuries were few in all trials. There was no significant difference in number of injured fish between treatment and control groups, or between late treatment and control groups. Many fish (24 %) were not sampled for descaling or other injuries due to passage delays. Time of fish passage through the bypass varied from 4 min to over 2 h. Most fish (68.2%) passed through without delay (< 8 min). Some fish (12.0%) remained in the bypass longer than 60 min. Plasma glucose, an indicator of stress, was significantly higher for treatment groups (185 mg/dL ± 44, mean ± SD) than control groups (126 mg/dL ± 37) 3 h after treatment. Plasma glucose levels remained significantly higher than baseline levels (103 mg/dL ± 36) longer in treatment (12 h) than control groups (24 h). Nitrogen supersaturation was 124% and total dissolved gas pressure was 116% in water exiting the bypass facility. Recommendations for future evaluations are included.

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Introduction

Four races of chinook salmon *Oncorhynchus tshawytscha* (i.e. fall, late fall, winter, and spring run), and a run of steelhead trout *O. mykiss* inhabit the Sacramento River in northern California. Chinook salmon runs are named according to when they enter San Francisco Bay on their upstream spawning migration. Salmonid populations in the Sacramento River basin have declined substantially during the past 25 years. Estimates of winter chinook[1] adult spawning escapement (escapement) decreased from a high of 117,808 in 1969 to 189 in 1994 (Inland Fisheries Branch, California Department of Fish and Game [CDFG], Red Bluff). Fall chinook escapement has been variable from lows of less than 40,000 in 1980 to a high of 139,966 in 1988. Although fall chinook escapement was 83,951 in 1994, it has become increasingly dependent on hatchery production (Cramer 1991). Late-fall chinook escapement decreased from 38,752 in 1969 to 10,370 in 1992[2]. Spring chinook escapement decreased from 26,505 in 1969 to 2,528 in 1994. Wild steelhead trout have declined to a few relic populations (McEwan and Jackson 1996).

Passage problems for adults and juveniles at Red Bluff Diversion Dam (RBDD) have contributed to the decline in anadromous salmonids. Studies initiated by this office in 1982 (Vogel et al. 1988; Vogel 1989) culminated in the replacement of the former, ineffective fish louvers and bypass at the Tehama-Colusa Canal (TCC) headworks with rotary fish screens and a new bypass facility in 1990. An evaluation of the new fish screens and bypass must be conducted to ensure they meet design objectives.

Raising the dam gates at RBDD during the nonirrigation season has reduced impacts on migrating salmon (U. S. Fish and Wildlife Service [USFWS] 1990). The impoundment at RBDD and the 5.2-m static head are lost when the dam gates are raised, leaving pumping as the only method to elevate water to the TCC. Alternative actions to protect fisheries while pumping water to the TCC include use of Archimedes and internal helical screw pumps (U. S. Bureau of Reclamation [Reclamation] 1992). Funding has been provided for a research pumping plant to study the feasibility of this concept. The research pumping plant would use the existing bypass, with modifications, to return fish from an evaluation facility back to the river.

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[1]The winter run was listed as endangered by the California Fish and Game Commission in May 1989 (California Code of Regulations, Title XIV, Section 670.5, Filed 9-22-89) and as threatened by the National Marine Fisheries Service (NMFS) in November 1990 (Federal Register, March 20, 1990, Volume 55, Number 54). On January 4, 1994 the NMFS reclassified the Sacramento winter-run chinook to endangered, effective February 3, 1994 (Federal Register, Volume 59, Number 440).

[2]The current practice of raising the dam gates at Red Bluff Diversion Dam during the nonirrigation seasons precludes making estimates spawning adult late fall chinook. The last estimate was made in 1992.

The new fish screens at RBDD deflect juvenile salmonids efficiently at diversions less than 34 m^3/s according to routine entrainment sampling (Johnson 1991, 1993; Johnson and Croci 1994; Croci and Johnson 1995). However, large amounts of air entrapped within the new bypass conduits and gate structure create turbulence which may cause injury to juvenile salmonids. The former bypass also had problems with entrained air, and caused an estimated 1.6 to 4.1% mortality to juvenile chinook salmon (Vogel et al. 1988).

Pilot study results indicate descaling may occur to fish in the bypass at RBDD (Big Eagle et al. 1993). In vitro studies conducted by other investigators link descaling with mortality. Bouck and Smith (1979) found that removal of slime and scales from 25% of the body area of juvenile coho salmon *O. kisutch* caused no mortality in fresh water but resulted in 75% mortality after 10 d captivity in seawater. Matthews (cited in Scully and Buetner 1986) observed less than 5% mortality after 16 d, and 100% mortality after 25 d in captive chinook salmon smolts descaled 40% or more in at least 2 of 10 body zones. Experimental descaling (10 to 20%) of juvenile chinook salmon resulted in 100% survival over a 72-h captive period (Matt Mesa, National Biological Survey [NBS], Cook, Washington, personal communication). Stress responses associated with descaling can effect survival by depressing immune competence and predisposing fish to disease (Wedemeyer and Wood 1974; Peters et al. 1988).

Previous residence time tests by Big Eagle et al. (1993) revealed juvenile chinook salmon can remain in the bypass longer than 15 min. Delay in passage could be harmful if total dissolved gas pressure (TGP) in the bypass is high and gas bubble disease occurs. Gas bubble disease can form quickly during exposure to high TGP and can cause significant mortality to juvenile and adult salmonids in the Columbia River (reviewed by Weitkamp and Katz 1980). TGP's from 106% to 120% decreased swimming performances of juvenile chinook (Schiewe 1974). Bayer et al. (1976, cited in Weitkamp and Katz, 1980) found that physiological effects occurred within 60 to 90 minutes at all TGP levels. Greatest effects at 117% TGP occurred 27 h after first exposure and 11 h of exposure at 120% TGP. Experimental groups of fish exposed to 120% TGP until 50% mortality occurred recovered 2 h after transfer to water at ambient saturation levels. If TGP is high in the bypass, fish remaining longer than 60 min could suffer mortality or increased vulnerability to predation (i.e. decreased swimming performance) for an extended period after exiting the bypass.

Plasma glucose is commonly used as an index of stress in fish (Wedemeyer et al. 1990). Stress triggers release of corticosteroids from the interrenal tissue which induce plasma glucose elevation (Leach and Taylor 1980). Multiple stresses result in cumulative changes in plasma glucose levels in salmon (Maule et al. 1989). Therefore, handling inherent to this study (i.e. transporting and recapturing) may preclude detection of stress associated with the bypass.

The goal of this project was to determine if the current bypass at RBDD can operate with minimal loss or harm to downstream migrating anadromous juvenile salmonids.

Specific objectives were to:

1. Compare survival of juvenile salmonids which pass through the bypass (treatment) to those which do not (control).

2. Compare descaling and other injuries between treatment and control groups to evaluate non-lethal effects of fish passage.

3. Determine time of fish passage and total dissolved gas pressure in the bypass.

4. Investigate feasibility of plasma glucose as an indicator of fish stress associated with the bypass at Red Bluff Diversion Dam and the Red Bluff Research Pumping Plant.

Study Area

The RBDD and TCC structures were completed in 1964. They are located 391 km upriver from the mouth of the Sacramento River approximately 6.4 km southeast of the city of Red Bluff (Figure 1). The RBDD diverts water into the TCC and the Corning Canal. Water (0.85 m^3/s) is periodically diverted to the Tehama Colusa Fish Facility. The bulk of the water continues through the TCC to irrigation districts for agricultural and wildlife refuge use.

The fish bypass transports fish screened from the TCC back to the Sacramento River downriver of the RBDD. It includes four bypass entrances, four 122-cm (4-ft) diameter conduits, one gate structure, two 152-cm (5-ft) diameter conduits, and one outfall structure (Figure 2). Water entering bypasses one and two remains separate from water entering bypasses three and four throughout the bypass facility. The bypass entrances are located equidistantly along a series of 32 drum screens. Each bypass entrance comprises a channel, metal ramp, and adjustable weir. Fish are directed by the metal ramp to the entrapping weir and entry into the 122-cm (4-ft) conduit (Figure 3). This design entraps fish over a range of river elevations. There is an open area under the adjustable weir and metal entrance ramp before draining into the 122-cm (4-ft) conduit. Conduits one and four originate farther from the gate structure, and are longer (104 m; 341 ft) than conduits two and three (84 m; 276 ft). Air entrained at the bypass entrances can escape at the gate structure (Figure 4). The gate structure redirects water into two 152-cm (5-ft) conduits which run parallel 388 m (1,273 ft) to the outfall structure (Figure 5). In the gate structure, water from bypasses one and two enter a common chamber above bypass conduits one and two. A separate chamber is common to bypasses three and four (Figure 4).The fish bypass was designed to pass a total flow of 6.79 m^3/s (240 ft^3/s).

Methods

Survival

Comparisons of survival were made between experimental fish which passed through the bypass facility at Red Bluff Diversion Dam (treatments) and fish which did not (controls). Two groups were used to assess survival associated with individual bypass conduits.

Twenty-thousand fall-chinook salmon presmolts (fish) with fork length ranging from 50 to 131 mm (75 mm ± 11; mean ± SD; N=4,729) were transported from Coleman National Fish Hatchery to a 15,508-L fiberglass tank at the Northern Central Valley Fish and Wildlife Office on May 10. Experimental fish were determined to be presmolts based on race, average fork length (fall chinook at 75 mm) presence of parr marks and non-deciduous scales. Treatment groups were larger (N~160) than controls (N~100) for the first 20 trials to allow for lower recapture rates for treatment fish. After trial 20 treatment groups were reduced and equal in size (N=140) to lessen delayed mortality associated with fish density. Control live car densities were greater or equal to treatments and always less than 101 fish.

Fish were counted into 28.3-L live-cars and deprived of feed 48 h prior to treatment, and fed a sustaining diet (0.02% body weight per d) of 0.21-cm Oregon Moist Pellets. Fish were emersed in a weak solution (16 mg/L) of Bismarck Brown Y for 20 min to distinguish experimental from non-experimental fish. Live-cars containing experimental fish were transferred to the bypass in a 1,327-L fiberglass distribution tank with four aerators and air supply. Fish remained submerged during all transfers to minimize handling stress.

Bypass entrance flows (m^3/s) were estimated prior to fish introduction. Water velocities were taken at 0.6-m intervals from surface to bottom (4.3 m) 1 m from the bypass entrance weirs with a model 2100 Swoffer® velocity meter. Flows were then estimated as the product of mean velocity (m/s) and channel cross-section (m^2).

Experiments of treatment and control fish were conducted contiguously using similar procedures. Known-sized groups were poured into the water from heights of 0.4 m directly into the 122-cm conduit at the bypass entrance (Figure 3) and controls into the mouth of the recapture net at bypass terminus (outfall structure; Figure 2 and 5). Fish were recaptured with a 9.1-m or 12.2-m fyke net (the longer net was used after trial 6). The mouth of the net was attached to a heavy metal frame which fit into the outfall's stop-log slots. The frame was equipped with casters on the downstream-side of the frame to ease raising and lowering the net. A scaffold and winch was affixed to the outfall structure to raise and lower the frame. The front end of the net (3.05 m back from the throat) had 0.64-cm delta-style mesh and 0.32-cm delta mesh for the remaining length The cod-end of the net was equipped with a 280-L live box. Both nets covered the entire outfall opening (1.83 x 1.83 m) without meaningful gaps (>0.32 cm) and therefore is assumed to have captured all fish exiting the bypass.

Trials utilizing common bypass conduits were conducted at least 24 h apart to negate mixing between trials. The fyke net was deployed for a 15-min period prior to introduction of experimental fish to determine if nonexperimental fish or experimental fish introduced the previous day were exiting the bypass. Control fish were held in the live box 5 min to insure they remained in the live box at least as long as treatments. Minimum time of fish passage through the bypass was estimated to be 4 min. Therefore, the fyke net was fished for 9 min after introduction of treatment fish to limit live-box exposure to 5 min. The net was redeployed for 5 min, after removing treatment fish from the live box, to recapture fish delayed in passage (see *Descaling*).

Recaptured treatment and control fish were decanted from the live box into separate live cars and then placed in common 625-L circular tanks for a 7-d observation period. Tanks received a flow of 49 L per min, directed to insure both samples received the same water quality, flow, and temperature. Fish were observed for 7 d after treatment. Live cars were inspected daily for mortalities. Moribund treatment and control fish were removed, enumerated, and examined for evidence of physical injury. Survivors were transported to the river and released.

Descaling and other injuries

Three treatment groups were used to assess descaling and other injuries associated with individual bypass conduits. Control and treatment groups were randomly subsampled from fish recaptured in survival experiments (N=25). Late-treatment groups were fish recaptured more than 8 min after introduction (N was dependent on total catch of late-treatment groups).

We hypothesized that descaling scores would differ between the control fish, treatment and late-treatment groups. Fish remaining in the bypass system longer than the 4½-min passage time for water were considered delayed (Table 1). Additionally, we assume that 80 to 100-mm chinook salmon would be incapable of remaining in the bypass conduits longer than 7 min without finding refuge from the main current. This assumption is based on studies by Fields et al. (1954 as cited in U. S. Army Corps of Engineers 1990) who estimated a maximum sustainable swimming speed of less than 0.6 m/s for coho salmon of a similar size (90 mm).

Fish were euthanized in 200 mg/L tricaine (MS-222), examined for descaling and injuries, weighed, and measured. Fish of trials 1 through 13 were euthanized and examined 7 d after treatment. Fish from later trials were examined on the day of treatment to improve our evaluation of the direct effects of fish passage through the bypass system.

Percent descaled area was estimated by visual comparisons of delineated body zones. Nine approximately equal body areas were defined and divided into 4 equal sections for a total of 36 zones (Basham et al. 1982). Descaling was estimated in terms of sub-zone equivalents. Thus, possible descaling score range was 0 to 36, with each increment equal to about 2.8% descaling. Other external injuries were noted and included frayed or eroded fins, body lesions, and vent and mouth hemorrhaging.

Time of fish passage

Calculated time of passage for fish swimming at 0.6 m/s (maximum speed; see *Descaling* ... in Methods) against the flow ranged from 5 min 9 s to 6 min 54 s. Therefore, we might assume experimental fish remaining in the bypass longer than 8 min escaped the main current and were delayed in passage.

Water velocity (mean; m/s) through the four bypass conduits was determined with fluorescein dye. Flow entering all bypasses was measured prior to dye tests. Time of fish passage was estimated using marked fish. Fish were marked with a florescent spray dye to distinguish introduction time and bypass (Phinney et al. 1967). Fifteen groups (*N*=80) of fish were introduced into bypass entrances. Three groups were introduced 1 m before the bypass weirs, and 12 groups, directly above the 122-cm conduit openings (Figure 3). Fish were recaptured with a 9.1 m fyke net equipped with a 9.5 L live box. The live box was emptied at 2-min intervals for 74 to 142 min after introduction. Fork length (mm), weight (g), time of introduction and recapture, and bypass number were recorded for all recaptured fish.

TGP was measured at the first and last bypass entrances (one and four), both gate structure chambers, both outfall structure openings, and at a site approximately 100 m downriver from the outfall structure. TGP was determined with a Weiss® saturometer. Water temperature (°C), dissolved oxygen (mg/L) and nitrogen supersaturation (%) were also determined. Dissolved oxygen was measured with a YSI® dissolved oxygen meter.

Plasma Glucose

Plasma glucose (mg/dL) was compared between treatment and control fish to characterize stress associated with the bypass at RBDD. All fish were fed similar diets for 2 months prior to treatment and were deprived of feed 48 h prior to treatment. Baseline plasma glucose (*N*=12) was determined immediately before treatments were initiated. Treatment fish were counted, transported to the bypass, introduced into the 48-cm conduit of bypass four, recaptured with a fyke net and live box at the outfall structure, and transported back to the fish holding facility using methods described under *Survival*. Control fish received the same handling as treatment fish except they were introduced directly into the throat of the fyke net and did not pass through the bypass. Different control (*N*=12) and treatment fish (*N*=12) were sampled 0, 1.5, 3, 6, 12, 24, and 48 h after treatment. Fish sampled at different times after treatment were held in separate live-cars to prevent stress from periodic sampling. Sampled fish were immediately placed in 200-mg/L MS-222 and were completely anesthetized in less than 1 min. Blood was collected in a 0.25-mL, ammonium-heparinized microhematocrit tube from the caudal vasculature. All sampling for each group was completed within 5 min. Plasma was separated from blood samples by centrifugation. Plasma glucose was determined by hexokinase method (Sigma Diagnostics, St. Louis, Missouri) within 30 min after centrifugation.

Data Analyses

Significance levels for all analyses in this study were at $P<0.05$. Significance of F values for all ANOVA's in this study were determined using random permutations ($P<0.05$; N=10,000; Edgington 1986). Trials were pooled to illustrate level of mortality, descaling, and other injuries in comparisons between groups.

Survival.—The null hypothesis that there was no difference in survival between control and treatment fish was tested using Fisher's exact test (SYSTAT, Inc 1992). Results were pooled for all trials and bypasses, and all trials by bypass at day 3 and day 7 after trials.

Descaling and other injuries.-The null hypotheses of no difference in descaling score between control and treatment, and control and late-treatment fish were tested using ANOVA. Length and weight were analyzed with the same experimental design and statistical procedure.

The null hypothesis that there was no difference in number of injured fish between control and treatment fish, and control and late-treatment fish were tested using Fisher's exact test.

Time of fish passage.-Time of fish passage was characterized by cumulative recapture (%) at the outfall structure versus time after introduction into bypass entrances. The null hypotheses that there were no differences in weight or length between fish recaptured ≤ 8 min and > 8 min after introduction were tested by trial using ANOVA.

Plasma glucose.—The null hypotheses that there were no differences in plasma glucose between control and treatment fish for each time after treatment were tested using ANOVA (i.e. seven planned comparisons). The null hypotheses that there were no differences in plasma glucose between each treatment group at each time after treatment and baseline fish were tested using ANOVA (i.e. 14 planned comparisons).

Results

Survival

Fifty-eight groups amongst the four bypasses were used to assess survival associated with individual bypass conduits. Trials were conducted from 26 May through 7 July 1994. No experimental fish from previous trials were captured the day following introduction. However, thirteen nonexperimental chinook (60 to 90 mm) were captured before treatment 8. Experimental fish were marked with Bismark Brown Y in subsequent treatments to distinguish them from naturally produced fish or those from previous treatments. Observations were made by divers using snorkels on all net sizes used in timing experiments. Experimental fish tended to delay, or hang, immediately in front of the live box. Therefore, it was necessary to "work" these fish into the live box by retrieving the net mouth to the surface first and then progressively raising the net back to the box.

No direct mortality occurred in recaptured treatment (N=5,253) and control (N=6,080) fish. Survival was high 3 d after treatment (99.4%; N=5,224), with no significant difference in survival between treatment and control groups (P=0.24; Table 2). Many treatment fish (40%) were not sampled for survival due to passage delays. Survival was greater than 90% for control (91.8%) and treatment fish (92.8%) 7 d after trials, with significant difference between groups (P=0.049). Differences however, were inconsistent with higher survival rates in treatment than control groups, suggesting 7-d survival was dependent on factors other than treatment effects.

Descaling and other injuries

The first twelve treatment groups were not included in the analysis of descaling because post-trial residence in live-cars (7 d) confounded results (contributed to higher descaling). In subsequent trials, analysis occurred on the same day as the treatment.

Mean descaling score was low for control (0.21 ± 1.19, mean ± SD; N=1,159), treatment (0.21 ± 1.13; N=1,166) and late-treatment fish (0.26 ± 1.19; N=247; Table 3). There was no significant difference in descaling score between, control and treatment (P=0.904), or control and late-treatment (P=0.21) fish for any of the trials. There was no significant difference in mean length (P=0.67) and weight (P=0.95) of control and treatments, or between length (P=0.42) and weight (P=0.97) of control and late-treatment groups.

Number of injured fish was low (≤3.1% per trial) for 58 trials (Table 4). Injuries to experimental fish included frayed fins, fins with > 30% erosion, lesions, and vent and mouth hemorrhages. No major fin or eye hemorrhaging occurred. Dye, necessary for distinguishing experimental fish, obscured minor fin and eye hemorrhages, precluding valid comparison between groups. Frayed fins accounted for 64.4%, and body lesions 26.0%, of the injuries. There was no significant difference in number of fish injured between control and treatment, or control and late-treatment groups (P>0.05)fish.

Time of fish passage

Fifteen trials were conducted to estimate time in passage, four per bypass except bypass 3 which received three. Nine minutes after release fewer fish were recaptured in bypass one than in bypass four (difference≤6.6%; Table 5). Flows were also significantly higher (difference=0.79 m^3/s) in bypass one than in bypass four. However, there was no significant difference between bypasses two and three in number of fish recaptured 9 min after introduction even though flows were significantly higher (mean≥0.65m^3/s) in bypass two.

Fish introduced to the bypass system 1-m upstream from the bypass entrance weirs were recaptured within 60 min after introduction less frequently (65%) than fish introduced above the 122-cm conduit openings (97.2%) in bypasses three and four

(Figure 6). Fish introduced above the weirs probably escaped the bypass by swimming against the current into the desilting basin. All fish introductions for survival, descaling, and glucose tests occurred directly above the 122-cm conduit openings to prevent escape. Fluorescein dye introduced into bypass entrances at water velocities of 1.95 to 2.41 m/s reached the outfall structure in 3 min 42 s to 4 min 35 s (Table 6).

Time in transit through the bypass for fish released directly above the 122-cm conduit openings was similar in bypasses one, three, and four and 60 to 94% were recaptured within eight minutes after introduction (Figure 6). Recapture rates decreased 8 min after introduction. Nearly all (87 to 100%) fish were recaptured by 90 min after introduction. Fewer fish (46 to 63%) were recaptured by 8 min after introduction into bypass two. Many fish (2 to 37%) remained in bypass two longer than 90 min.

Delay in passage was not associated with weight or length. Mean weight was not significantly different between fish recaptured prior to 8 min after release (early) and fish recaptured later (late). Mean length was not significantly different (P>0.05) between early (77 mm ± 7, mean ± SD; N=59) and late groups (81 mm ± 4; $N=18$).

TGP increased from 103% at bypass entrances to 116 and 117% as water passed through the bypass conduits, and decreased to 103 and 108% 100 m downriver from the outfall structure (Table 7).

Plasma glucose

Plasma glucose was 103 ± 36 (mean ± SD) in baseline fish sampled before treatment (N=12; Table 8). Plasma glucose levels remained significantly higher than baseline levels longer in treatment fish (12 h) than in control fish (24 h).

Discussion

Inference of study results should be limited to naturally produced chinook salmon of similar size. Repetition of the study with smaller salmon would be necessary to assess effects of the bypass on smaller wild chinook.

Survival

Survival was greater than 90% for control (90.1%) and treatment groups (91.4%) 7 d after trials. Survival was also greater than 90% for chinook salmon and steelhead trout during the pilot study in 1993 (96.2 to 100 % 2 d after treatment; Big Eagle et al. 1993). Vogel et al. (1988) estimated overall survival to be between 95.9% and 98.4% for juvenile chinook salmon passing through the former fish louver bypass system at RBDD. Other investigators found high salmonid survival when studying bypass systems that operate at lesser flows (Neitzel et al. 1986, 1987, 1989).

Mortalities in control and treatment fish began to increase 3 d after treatment and were showing symptoms of columnaris disease *Flexibacter columnaris*. Columnaris outbreaks are temperature related, and can be explosive in cultured salmon when water temperatures exceed 18.3 °C (USFWS 1981). Severe mortalities (> 25%) occurred only in tanks supplied by the two longest of four water lines, and when maximum water temperature at water source exceeded 16.7 °C. High ambient temperatures may have caused higher water temperatures in tanks supplied by longer water pipes. Water temperature should be monitored continuously in all circular tanks during future studies.

Many treatment fish (40.0%) remained in the bypass longer than 9 min and were not sampled for survival. Delayed fish exited the bypass over a period of several hours (see *Time of fish passage*). Limitation of live box exposure to 5 min, and standardization of transport time and densities between treatments precluded capture of sufficient delayed fish for statistical comparison to control fish. Therefore, delayed mortality for fish remaining in the bypass longer than 9 min was not determined. However, no immediate mortality occurred in fish recaptured between 10 to 15 min after introduction for late-treatment of the descaling study (N=344), or in fish recaptured between 10 to 142 min after introduction during timing tests (N=232).

A portion of fish remaining in the bypass longer than 9 min became entrained in the gate structure chambers (see *Time of fish passage*). High TGP (114%) in the gate structure chambers may reduce survival of fish after prolonged exposure. Also, violent turbulence in the gate structure chamber above bypasses one and two, resulting from air entrainment at bypass entrances, could cause fish to collide with the chamber walls. Elimination of fish access to gate structure chambers is not feasible (Marcin Whitman, NMFS, Santa Rosa, California, personal communication); therefore, survival and condition of fish entrained into the gate structure chambers should be determined. In future studies, the effects of gate structure chamber entrainment could be isolated, and sample size increased by introducing some treatment fish into the gate structure chambers rather than bypass entrances.

Descaling and other injuries

Descaling and other injuries could not be attributed to passage through the bypass. Other investigators found little or no descaling or other injuries in salmonids when studying bypass systems operating at lesser flows (Neitzel et al. 1986, 1987, 1989). Future studies should evaluate different length groups from those included in this study. Particular emphasis should be placed on fry (<46 mm) which may be more vulnerable to injury during passage.

Many treatment fish (23.9%) remained in the bypass longer than 15 min and were not sampled for descaling or other injuries (see *Survival*). Sample sizes for fish recaptured 9 to 15 min after introduction were too small for sufficient statistical comparisons with controls. As stated in *Survival*, descaling and other injuries to fish delayed by entrainment in the gate structure chambers should be assessed by introducing treatment fish into gate structure chambers in future studies.

Time of fish passage

Higher flows may cause fish to be delayed in passage. Fewer fish were recaptured by 9 min in bypass one when flows were higher than bypass four. However, there was no significant difference in number of fish recaptured 9 min after introduction between bypasses two and three even though flows were greater in bypass two.

Bypass two had a greater incidence of post 8-min residualization (37 to 54%) than other bypasses (6 to 40%). Many of the fish introduced into bypass two probably escaped the bypass by swimming under the adjustable weir and through a 2.5-cm gap between the bottom, upstream side of the metal ramp and the bypass entrance floor (Figure 3). The 2.5-cm gap is unique to the ramp in bypass two, which was rebuilt after its collapse during the summer of 1993. The gap should be eliminated before timing tests resume. The gap in the entrance ramp and larger portion of delayed fish in bypass two indicates many fish swim under the adjustable weirs and hold under the bypass entrance ramps even when they are introduced directly above the 122-cm conduits in all four bypasses.

Furthermore, accessible velocity refugia exists in the two gate structure chambers. Dyed fish from survival and descaling tests (N=1 to 5) were observed in both gate structure chambers from 32 to 93 min after introduction into bypass entrances (Appendix 22). However, poor visibility prevented complete census of fish in gate structure chambers. Flows were consistently higher in bypasses one and two. Air entrained at the bypass entrances cause turbulence, which appeared high in the chamber above bypasses one and two and always low in the chamber above bypasses three and four. Gate chamber turbulence, however, does not appear to contribute to entrainment since fish were observed in both chambers.

Rates of fish entrainment into the gate structure chambers should be determined as entrainment may be harmful (see *Survival*). Since visibility in the gate structure chambers is poor, entrainment must be determined by subtracting the number of fish recaptured at the outfall structure from those introduced at bypass entrances. This necessitates preventing fish from swimming under the adjustable weirs and holding under the entrance ramps (i.e. the other areas where fish are delayed). At the bypass entrances, metal entrance ramps could be replaced with concrete ramps, or areas under the adjustable weirs could be covered with sheet metal. Replacement with concrete ramps is recommended to avoid structural problems (i.e. collapses and gaps) in the future. Correlation between bypass flow and extent of entrainment in the gate structure chambers could then be investigated, and optimal flows for expedient passage determined.

Plasma glucose

The mean baseline plasma glucose was 103 mg/dL, while treatment fish increased to 183 mg/dL 6 h after treatment. Investigators who have measured stress induced changes in plasma glucose for hatchery juvenile chinook salmon (Rondorf et al. 1988) and rainbow trout (Woodward and Strange 1987) reported values similar to those found in this study. High SD in control fish 6 h after treatment indicates repetition of the experiment is necessary to verify results.

Higher plasma glucose 3 h after treatment and longer recovery time for treatment fish suggest passage through the bypass caused stress. Effects of multiple stressors are cumulative (Sigismondi and Weber 1988). Therefore, increases in plasma glucose may be smaller for fish that have not experienced handling prior to passage through the bypass, such as wild fish entrained into the forebay. Although stress is known to decrease swimming performance of juvenile chinook salmon (Sigismondi and Weber 1988), correlation of physiological stress responses to swimming performance have not been made.

We could not quantify the increase in plasma glucose resulting solely from passage through the bypass. However, it appears that plasma glucose levels could be used to rank stress associated with various treatments involving considerable fish handling as in our study. Therefore, plasma glucose measurement could be useful in comparing stress associated with different pumps at Red Bluff Research Pumping Plant.

Summary

1. Survival 3 d after trials was not significantly different between treatment groups of fall-run chinook smolts which passed through the bypass conduits and control groups which did not. Forty percent of treatment fish remained in the bypass longer than 9 min after introduction and were not sampled for delayed mortality.

2. Descaling and occurrence of other injuries was minimal, and not significantly different between treatment and control groups or between late-treatment (fish recaptured 10 to 15 min after introduction) and control groups. Twenty-four percent of treatment fish were not sampled for descaling or other injuries due to their prolonged time in passage.

3. Time of fish passage ranged from 4 min to more than 142 min. Experimental fish were observed in gate structure chambers 93 min after introduction into bypass entrances. Fish may also hold beneath the bypass entrance ramps. Delays in passage may be associated with higher bypass flows and turbulence. Total dissolved gas pressure was high enough (114%) in both gate structure chambers to warrant concern for fish delayed in passage.

4. Plasma glucose was significantly higher for treatment fish 3 h after trials than for control fish. Plasma glucose remained elevated longer in treatment (12 h) than in control fish (6 h). Plasma glucose measurement may be useful for comparing stress associated with various treatments (e.g. pumps, and flows) at Red Bluff Research Pumping Plant.

Recommendations

1. Repeat study using salmonid fry (28 to 40 mm) since they may respond differently to the bypass than presmolt salmonids.

2. Eliminate holding areas under metal entrance ramps to expedite fish passage and accurately assess extent of entrainment into gate structure chambers.

3. Introduce treatment fish into gate structure chambers rather than bypass entrances to isolate effects (i.e. survival, and descaling and other injuries) associated with entrainment in the gate structure chambers, and to increase sample size for entrained fish.

4. Determine time of fish passage at different bypass flows to allow operation of the bypass with minimal entrainment of fish in gate structure chambers.

5. Repair metal ramp in entrance of bypass two so that time of fish passage can be accurately estimated in future studies.

6. Investigate correlation between maximum water temperatures in circular tanks and mortality during future studies.

7. Plasma glucose measurement may be useful for comparing stress associated with various treatments (e.g. pumps, and flows) at Red Bluff Research Pumping Plant.

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References

Basham, L. R., M. R. Delarm, J. B. Athean, and S. W. Pettit. 1982. Fish transportation oversight team annual report, FY 1981: transport operations on the Snake and Columbia rivers. Technical Services Division, Northwest Regional Office, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Portland, Oregon.

Big Eagle, J. D., K. Brown, and J. P. Bigelow. 1993. Survival and condition of juvenile salmonids passing through the downstream migrant fish protection facilities at Red Bluff Diversion Dam on the Sacramento River, Spring 1993. Report No. AFF1-FRO-93-10. U. S. Fish and Wildlife Service, Red Bluff, California.

Bouck, G. R., and S. P. Smith. 1979. Mortality of experimentally descaled smolts of coho salmon (*Oncorhynchus kisutch*) in fresh and salt water. Transactions of the American Fisheries Society 108: 67-69.

Cramer, S. P. 1991. Contributions of Sacramento basin hatcheries to ocean and river escapements. S. P. Cramer and Associates, Sacramento, California. Prepared for California Department of Water Resources.

Croci, S. J. and R. R. Johnson. 1995. Entrainment evaluation of the Red Bluff Diversion Dam downstream migrant fish protection facilities, May - September 1994. U. S. Fish and Wildlife Service Annual Report. Northern Central Valley Fish and Wildlife Office, Red Bluff, California.

Edgington, E. S. 1986. Randomization tests. Marcel Dekker, Inc. New York, New York.

Johnson, R. R. 1991. Entrainment evaluation of the newly installed Red Bluff Diversion Dam downstream migrant fish protection facilities. Report No. AFF1-FRO-91-17. U. S. Fish and Wildlife Service, Northern Central Valley Fishery Resource Office, Red Bluff, California.

Johnson, R. R. 1993. Entrainment evaluation of the newly installed Red Bluff Diversion Dam downstream migrant fish protection facilities, October 1991 - October 1992. Report No. AFF1-FRO-93-02. U. S. Fish and Wildlife Service, Northern Central Valley Fishery Resource Office, Red Bluff, California.

Johnson, R. R. and S. J. Croci. 1994. Entrainment evaluation of the Red Bluff Diversion Dam downstream migrant fish protection facilities, May - October 1993. Report No. AFF1-FRO-94-05. U. S. Fish and Wildlife Service, Northern Central Valley Fishery Resource Office, Red Bluff, California.

Leach, G. J., and M. H. Taylor. 1980. The role of cortisol in stress-induced metabolic changes in *Fundulus heteroclitus*. General and Comparative Endocrinology 42:219-227.

Maule, A. G., Tripp, R. A., Kaattari, S. L., and C. B. Schreck. 1989. Stress alters immune function and disease resistance in chinook salmon (*Oncorhynchus tshawytscha*). J. Endocrinology 120: 135-142.

McEwan, D. and T. A. Jackson. 1996. Steelhead restoration and management plan for California. California Department of Fish and Game, Inland Fisheries Division, Sacramento, California.

Neitzel, D. A., C. S. Abernethy, and E. W. Lusty. 1986. A fisheries evaluation of the Richland and Toppenish/Status Canal fish screen facilities. Pacific Northwest Laboratory, Richland, Washington. Prepared for Thomas Clune, Project Manager, U. S. Department of Energy, Bonneville Power Administration, Portland, Oregon.

Neitzel, D. A., C. S. Abernethy, and E. W. Lusty. 1989. A fisheries evaluation of the Westside Ditch and Wapato Canal fish screening facilities. Pacific Northwest Laboratory, Richland, Washington. Prepared for Thomas Clune, Project Manager, U. S. Department of Energy, Bonneville Power Administration, Portland, Oregon.

Neitzel, D. A., C. S. Abernethy, E. W. Lusty, and S. J. Wampler. 1987. A fisheries evaluation of the Richland and Wapato Canal fish screening facilities. Pacific Northwest Laboratory, Richland, Washington. Prepared for Thomas Clune, Project Manager, U. S. Department of Energy, Bonneville Power Administration, Portland, Oregon.

Peters, G., M. Faisal, T. Lang, and I. Ahmed. 1988. Stress caused by social interaction and its effect on susceptibility to *Aeromonas hydrophila* infection in rainbow trout *Salmo gairdneri*. Diseases of Aquatic Organisms 4: 83-89.

Phinney, D. E., D. M. Miller, and M. L. Dahlberg. 1967. Mass-marking young salmonids with fluorescent pigment. Transactions of American Fisheries Society 96(2): 157-162.

Rondorf, D. W., J. W. Beeman, M. E. Free, and D. E. Liljegren. 1988. Correlation of biological characteristics of smolts with survival and travel time. U. S. Fish and Wildlife Service, National Fishery Research Center, Columbia River Field Station, Cook, Washington. Prepared for Dale Johnson, Project Manager, U. S. Department of Energy, Bonneville Power Administration, Portland, Oregon.

Schiewe, M. H. 1974. Influence of dissolved atmospheric gas on swimming performance of juvenile chinook salmon. Transactions of the American Fisheries Society 103:717-721.

Scully, R. J. and E. Buettner. 1986. Smolt condition and timing of arrival at Lower Granite Reservoir. Idaho Department of Fish and Game, Boise, Idaho.

Sigismondi, L.A. and L.J. Weber. 1988. Changes in avoidance response time of juvenile chinook salmon exposed to multiple acute handling stresses. Transactions of the American Fisheries Society 117:196-201.

SYSTAT, Inc. 1992. SYSTAT for Windows: Statistics, Version 5 Edition. Evanston, Illinois.

U. S. Army Corps of Engineers. 1990. Fisheries handbook of engineering requirements and biological criteria. North Pacific Division, Portland, Oregon.

U. S. Bureau of Reclamation. 1992. Appraisal Report: Red Bluff Diversion Dam Fish Passage Study. Mid-Pacific Region, Sacramento, California.

U. S. Fish and Wildlife Service. 1990. Evaluation of the measure of raising the Red Bluff Diversion Dam gates on improving anadromous fish passage based on observations of radio-tagged fish. U. S. Fish and Wildlife Service Report No. AFF1/FAO-90-10, Northern Central Valley Fisheries Resource Office, Red Bluff, California.

U. S. Fish and Wildlife Service. 1981. Diseases of hatchery fish. U. S. Government Printing Office, Washington D. C.

Vogel, D. A. 1989. Tehama-Colusa Canal Diversion and Fishery Problems Study. U. S. Fish and Wildlife Service Report No. FR1-FAO-89-6, Northern Central Valley Fisheries Resource Office, Red Bluff, California.

Vogel, D. A., K. R. Marine, and J. G. Smith. 1988. Fish passage action program for Red Bluff Diversion Dam. U. S. Fish and Wildlife Service Report No. FR1-FAO-88-19, Northern Central Valley Fishery Resource Office, Red Bluff, California.

Wedemeyer, G. A., B. A. Barton, and D. J. McLeary. 1990. Stress and acclimation. Pages 451-489 *in* C. B. Schreck and P. B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Wedemeyer, G. A., and J. W. Wood. 1974. Stress as a predisposing factor in fish diseases. Fish Leaflet, U. S. Fish and Wildlife Service, FDL-38.

Weitkamp, D. E., and M. Katz. 1980. A review of dissolved gas supersaturation literature. Transactions of the American Fisheries Society 109:659-702.

Woodward, C. C., and R. J. Strange. 1987. Physiological stress responses in wild and hatchery-reared rainbow trout. Transactions of the American Fisheries Society 116:574-579.

Table 1.—Estimated time for water passage through bypasses one and four, and bypasses two and three. If distributed evenly, each of the four bypasses is designed for a flow of 1.70 m^3/s to the gate structure and 3.40 m^3/s in each of the two 152-cm from the gate structrue to the outfall. Calculated water velocity in the four 122-cm conduits would be 1.5 m/s and in the two 152-cm conduits flow would be 3.40 m^3/s with calculated velocity of 1.9 m/s.

	Bypass to gate structure		Gate structure to outfall		
Bypass	length (m)	velocity (m/s)	length (m)	velocity (m/s)	Estimated passage min:s
1 and 4	104	1.5	388	1.9	4:33
2 and 3	84	1.5	388	1.9	4:20

Table 2.—Percent survival of control and treatment groups three and seven days after trials by bypass and all trials combined. Total number of trials are in parentheses. Significant differences between control and treatment groups in number alive and dead at three and seven days after trials is denoted by an asterisk (Fisher's exact test; $P<0.05$).

N		Three days		Seven days	
control	treatment	control	treatment	control	treatment
		Bypass 1 (14)			
1,351	1,257	99.2	99.5	89.6*	92.7*
		Bypass 2 (15)			
1,916	1,145	99.4	99.1	91.6	91.0
		Bypass 3 (14)			
1,367	1,404	99.1	99.5	90.3	92.0
		Bypass 4 (15)			
1,446	1,447	99.2	99.6	95.6	94.7
		Combined (58)			
6,080	5,253	99.2	99.4	91.8*	92.8*

Table 3.—Descaling scores (mean ± SD) of chinook salmon fingerlings for control, treatment and late-treatment by bypass. Possible score range was from 0 (no descaling) to 36 (total descaling). Score equals quarters of nine body zones descaled. Sample sizes are in parentheses.

Bypass	Control	Treatment	Late treatment
1	0.16±0.72(277)	0.28±1.19(280)	0.08±0.43(52)
2	0.25±1.20(305)	0.16±0.68(305)	0.63±1.96(57)
3	0.17±1.51(275)	0.12±0.72(276)	0.09±0.32(81)
4	0.26±1.19(302)	0.28±1.62(305)	0.32±1.34(57)
Combined	0.21±1.19(1,159)	0.21±1.13(1,166)	0.26±1.19(247)

Table 4.—Percent of injured chinook salmon fingerlings in control, treatment and late-treatment groups for trials conducted after June 6 combined by type of injury. Sample sizes are in parentheses.

Injury	Control (1,157)	Treatment (1,165)	Late treatment (241)
Frayed fin	1.5	2.1	2.5
Eroded fin (>30%)	0	0.2	0
Body lesion	0.8	0.6	0
Vent hemorrhage	0	0.2	0
Mouth hemorrhage	0.1	0.1	0
One or more of the above	2.3	3.1	2.5

Table 5.—Number of trials, flow (m^3/s) in corresponding 152-cm conduit (mean ± SD), and percent of chinook salmon fingerlings recaptured from 0 to 9 min after introduction (mean ± SD) by bypass. Trials were comprised of 137 to 160 chinook salmon. Chinook salmon in each trial were introduced into the bypass entrances in two equal subgroups, 1 min apart. Significant differences between bypasses 1 and 4 (comparison A), and bypasses 2 and 3 (comparison B) for flows and percent of introduced salmon recaptured are marked with an asterisk (ANOVA, $P < 0.05$).

	Comparison A		Comparison B	
	Bypass 1	Bypass 4	Bypass 2	Bypass 3
Trials	8	11	11	9
Flow	4.70 ± 0.11*	3.91 ± 0.11*	4.61 ± 0.25*	3.96 ± 0.20*
Percent recaptured	77.5 ± 5.4*	84.1 ± 4.7*	73.4 ± 11.4	74.8 ± 5.1

Table 6.—Flow (m^3/s) at bypass entrance (A), flow at corresponding 152-cm conduit (B), distance (m) from bypass entrance to outfall structure, time of passage for fluorescein dye and mean water velocity (m/s).

Bypass	Flow A	Flow B	Distance	Time (dye)	Velocity
1	2.35	4.76	492.7	3 min 54 s	2.11
2	2.41	4.76	472.6	3 min 42 s	2.13
3	1.95	4.04	472.6	4 min 25 s	1.78
4	2.09	4.04	492.7	4 min 35 s	1.79

Table 7.—Water temperature, dissolved oxygen, nitrogen supersaturation, and total dissolved gas pressure at seven locations associated with the bypass facility at Red Bluff Diversion Dam. Locations include bypass entrances 1 and 4, gate structure chambers, outfall structure openings, and the Sacramento River 100 m downriver from the outfall structure. Dashes indicate no sampling.

Location	Date	Water temperature (°C)	Dissolved oxygen (mg/L)	Nitrogen supersaturation (%)	Total dissolved gas pressure (%)
Bypass entrance 1	July 22	14.2	-	-	103
	Sept 9	14.6	10.8	107	103
Bypass entrance 4	July 22	14.2	-	-	103
	Sept 9	14.5	11.1	106	103
Gate structure chamber 1&2	July 22	14.1	-	-	114
Gate structure chamber 3&4	July 22	14.1	-	-	114
Outfall structure opening 1&2	July 22	13.9	-	-	117
	Sept 9	14.4	10.8	124	116
Outfall structure opening 3&4	July 22	13.9	-	-	116
	Sept 9	14.5	12.8	119	117
Downriver from outfall	July 22	13.8	-	-	103
	Sept 9	14.5	12.5	109	108

Table 8.—Baseline plasma glucose levels (mean ± SD; mg/dL) for chinook salmon fingerlings, and plasma glucose levels for control and treatment fish by time after trial (h). Sample sizes are in parentheses. Significant differences between control and treatment groups plasma glucose by time after trial are denoted by "a". Treatment and control groups with significantly higher plasma glucose than baseline fish are marked with "b" (ANOVA; P<0.05).

Time after trial	Baseline	Control	Treatment
-	103 ± 36 (12)	-	-
0	-	168 ± 71 (12)b	158 ± 40 (12)b
1.5	-	147 ± 54 (12)b	165 ± 44 (12)b
3	-	126 ± 37 (12)a	185 ± 44 (12)a,b
6	-	210 ± 100 (12)b	183 ± 48 (12)b
12	-	116 ± 51 (12)	159 ± 49 (12)b
24	-	109 ± 21 (12)	94 ± 19 (12)
48	-	95 ± 16 (12)	83 ± 20 (12)

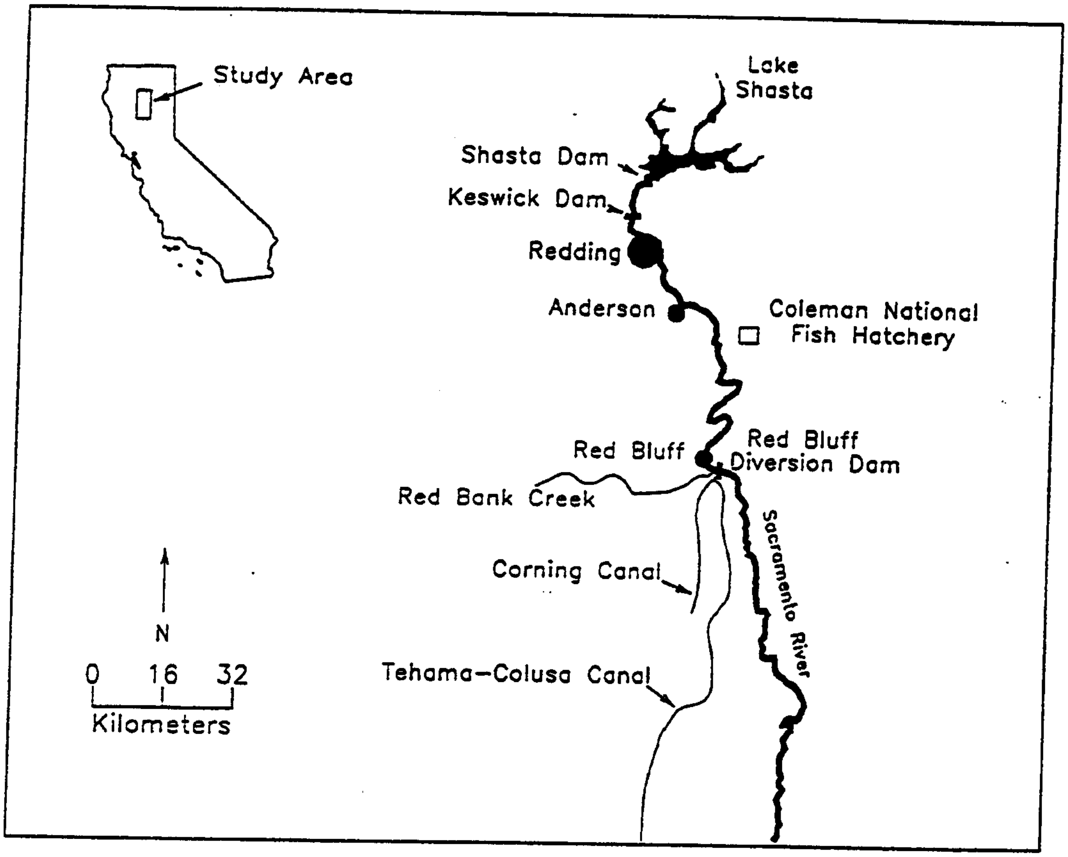

Figure 1.–Location of Red Bluff Diversion Dam, and the Tehama-Colusa and Corning canals with respect to Redding, Anderson, and Red Bluff, California.

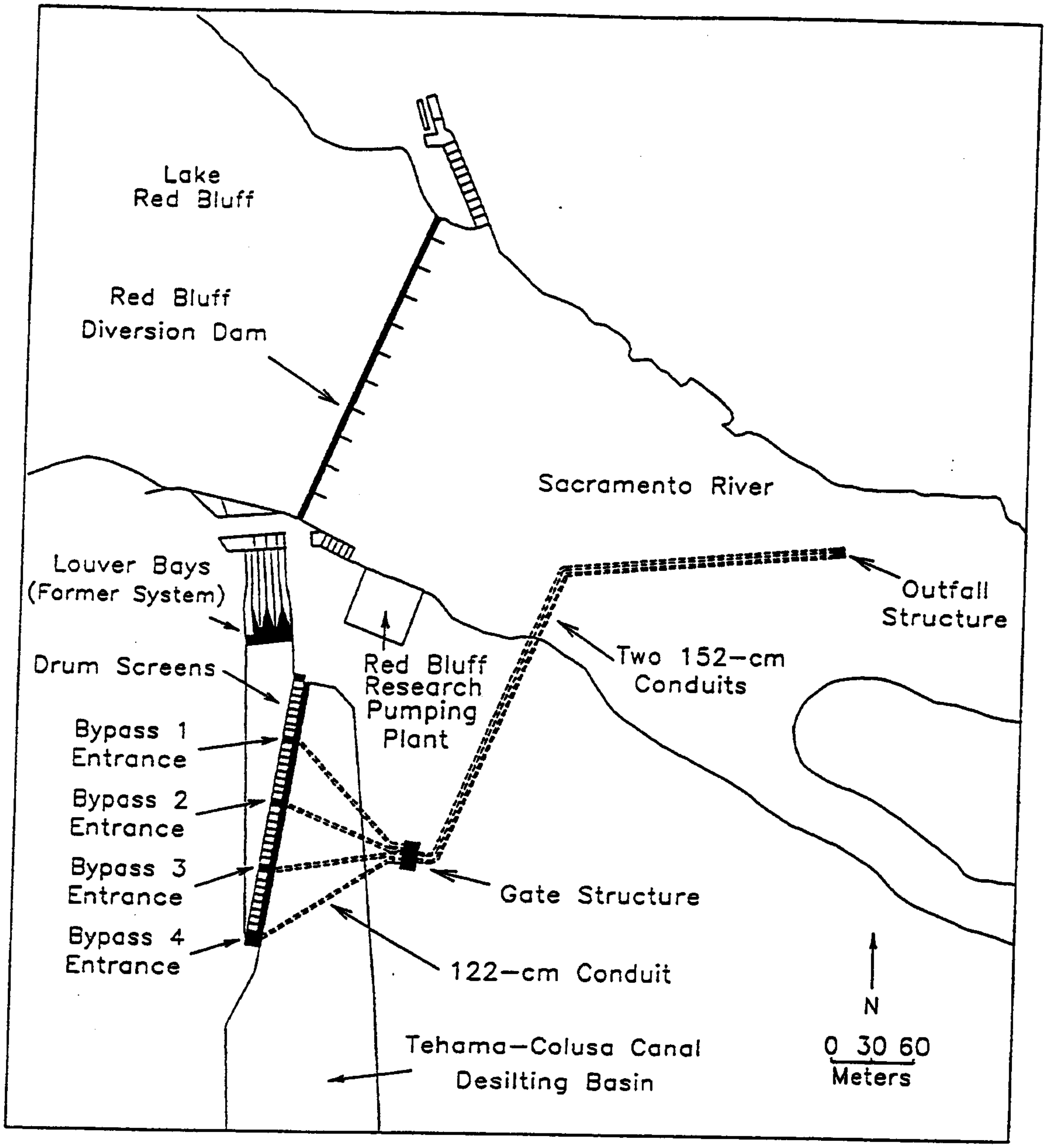

Figure 2.-Red Bluff Diversion Dam, Red Bluff Research Pumping Plant, and juvenile fish bypass facility including drum screens, bypass entrances, gate structure, and outfall structure.

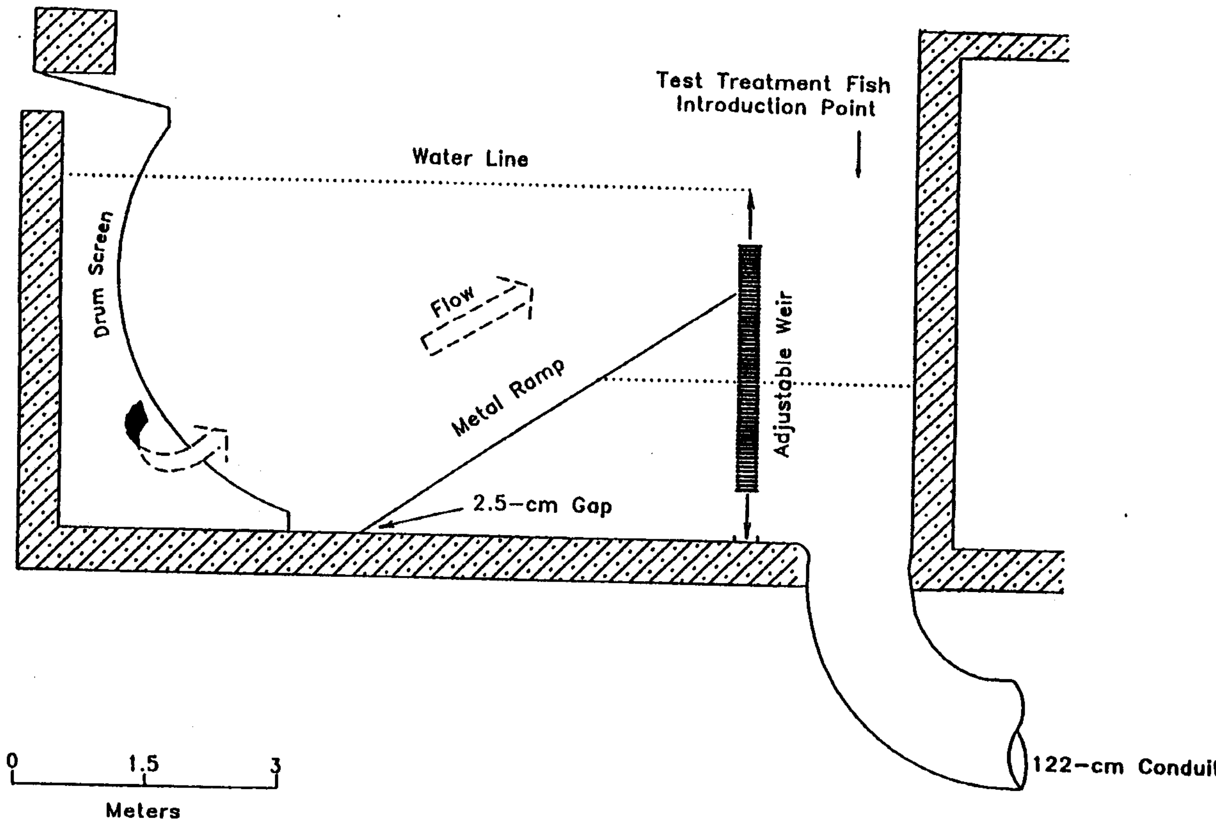

Figure 3.-Side view of one of four bypass entrances including test fish introduction site, metal ramp, adjustable weir, and 122-cm conduit opening. Gap between the floor and upstream end of the metal ramp (2.5 cm) is unique to bypass two.

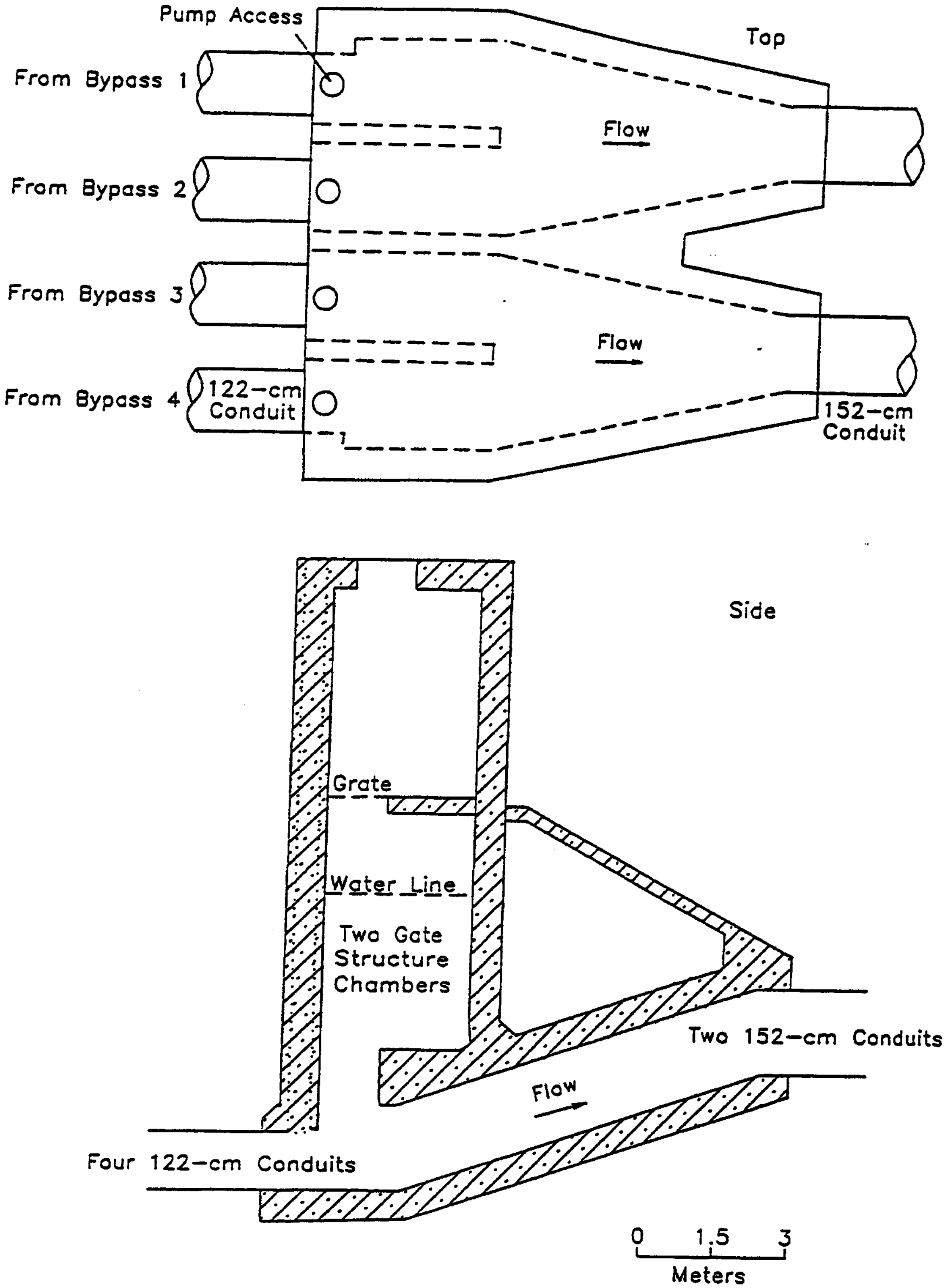

Figure 4.-Top and side view of gate structure including gate structure chambers.

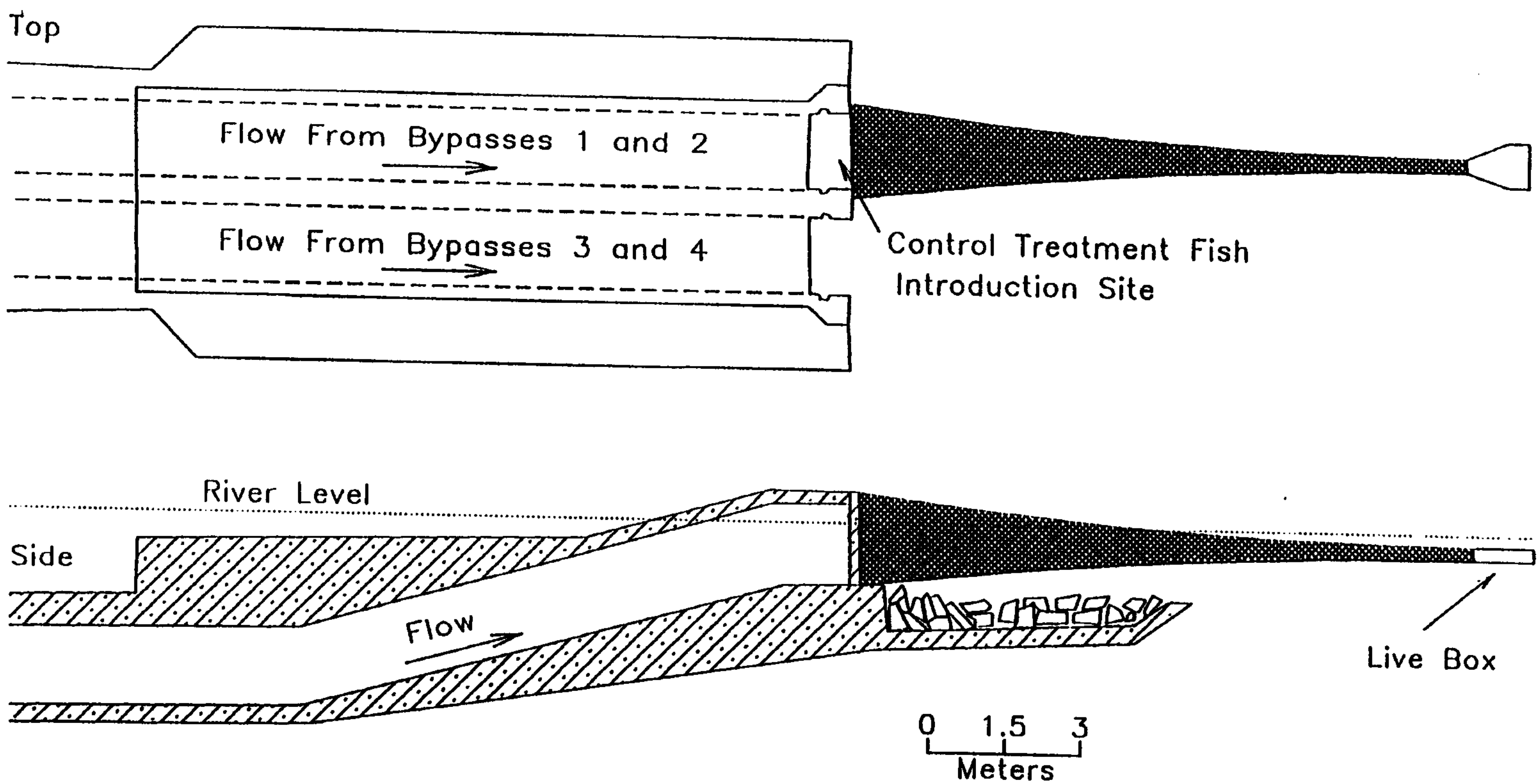

Figure 5.-Top and side view of outfall structure including both openings, control fish introduction site, 12.2-m fyke net, and live box. Fyke net was interchangeable between outfall structure openings.

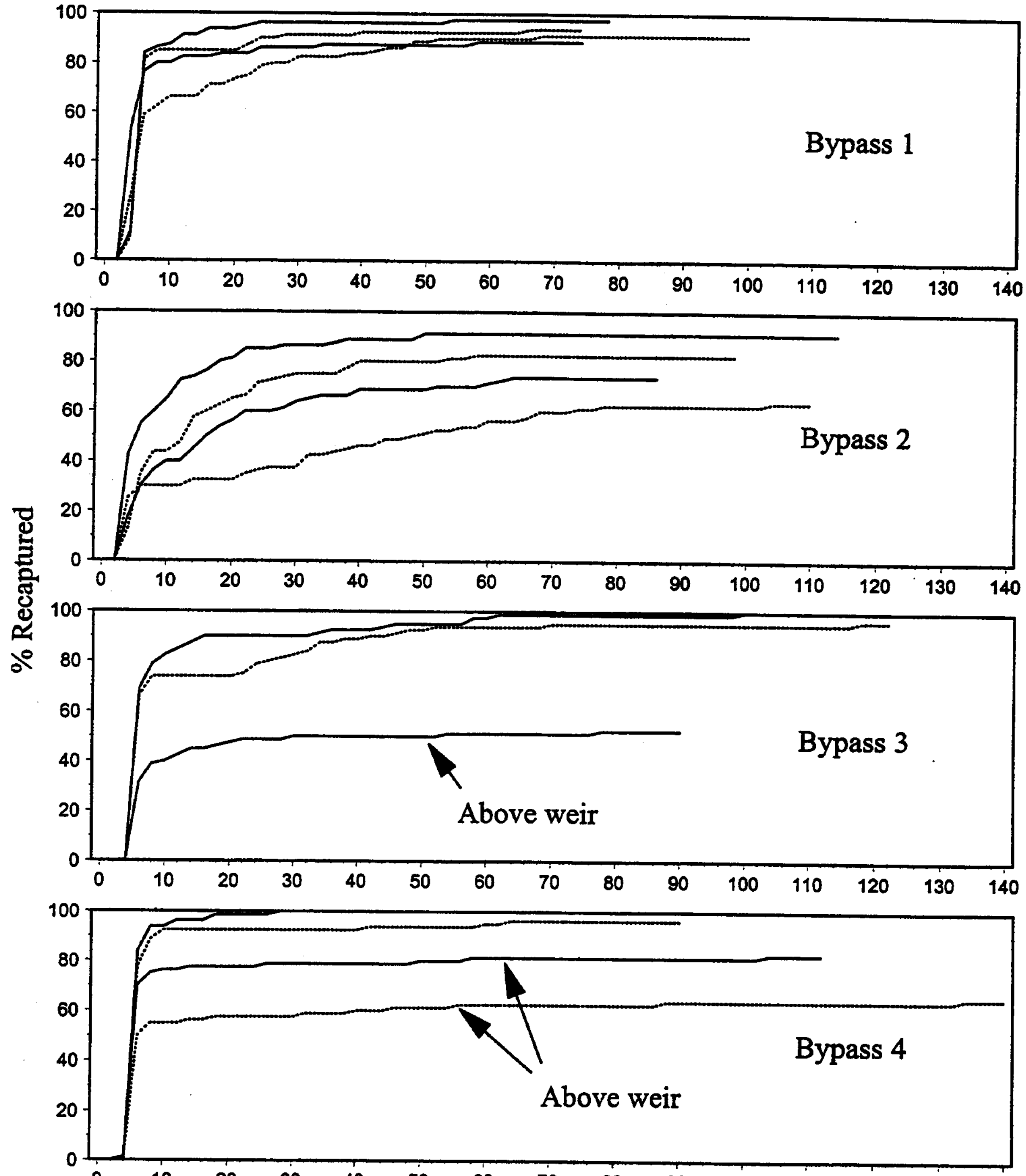

Figure 6.—Cumulative recapture of chinook salmon fingerlings at the outfall structure versus min after introduction into bypass entrances for 15 trials (*N*=80). Trials where fish were released 1 m before adjustable weirs are denoted as "above weir", others were released directly above 122-cm conduits. Bypass entrance flows were 2.26 m^3/s in bypass 1, 2.15 to 2.21 m^3/s in bypass 2, 1.87 m^3/s in bypass 3, and 1.92 m^3/s in bypass 4. Tests were conducted 18 to 23 May, 1994.

Appendix 1.—Sample size, **survival** 3 d after trials, and survival 7 d after trials of chinook salmon fingerlings in control and treatment groups for **bypass 1** from May to July 1994.

	N		3-d survival (%)		7-d survival (%)	
Date	control	treatment	control	treatment	control	treatment
May 26	99	125	100.0	100.0	100.0	100.0
May 31	100	107	99.0	100.0	99.0	98.1
June 2	100	133	98.0	99.2	80.0	85.0
June 7	75	75	98.7	98.7	90.7	90.7
June 9	75	75	98.7	100.0	72.0	74.7
June 13	100	86	100.0	96.5	90.0	84.9
June 16	100	72	100.0	100.0	82.0	94.4
June 20	100	80	99.0	100.0	91.0	93.8
June 22	100	95	100.0	98.9	94.0	83.2
June 24	100	92	99.0	100.0	97.0	100.0
June 28	100	81	100.0	100.0	98.0	96.3
June 30	100	76	100.0	100.0	94.0*	100.0*
July 5	100	87	98.0	100.0	94.0	97.7
July 7	100	73	100.0	100.0	99.0	98.6

Appendix 2.—Sample size, **survival** 3 d after trials, and survival 7 d after trials of chinook salmon fingerlings in control and treatment groups for **bypass 2** from May to July 1994.

	N		3-d survival (%)		7-d survival (%)	
Date	control	treatment	control	treatment	control	treatment
May 27	99	64	100.0	100.0	100.0	100.0
June 1	100	111	100.0	100.0	100.0	100.0
June 3	100	70	100.0	100.0	94.0	92.9
June 8	75	58	100.0	100.0	88.0	89.7
June 10	74	63	93.2	96.8	47.3	79.4
June 14	100	91	100.0	100.0	91.0	96.7
June 17	100	90	99.0	100.0	91.0	90.0
June 21	100	96	100.0	100.0	99.0	96.9
June 23	100	88	100.0	100.0	87.0	97.7
June 27	100	84	98.0	98.8	88.0	92.9
June 29	100	67	99.0	98.5	97.0	80.6
July 1	100	67	99.0	95.5	55.0	59.7
July 6	100	74	99.0	97.3	98.0	93.2
July 11	100	54	100.0	98.1	100.0	98.1
July 12	100	68	100.0	100.0	100.0	86.8

Appendix 3.—Sample size, **survival** 3 d after trials, and survival 7 d after trials of chinook salmon fingerlings in control and treatment groups for **bypass 3** from May to July 1994.

	N		3-d survival (%)		7-d survival (%)	
Date	control	treatment	control	treatment	control	treatment
May 27	106	99	100.0	100.0	99.1	100.0
May 31	113	96	98.2	97.9	96.5	93.8
June 3	100	137	98.0	100.0	91.0	92.0
June 7	75	75	100.0	100.0	90.7	90.7
June 10	73	75	98.6	98.7	65.8	81.3
June 13	100	87	99.0	98.9	82.0	88.5
June 17	100	80	100.0	98.8	98.0	93.8
June 20	100	75	98.0	100.0	89.0	96.0
June 23	100	84	100.0	98.8	77.0	88.1
June 24	100	70	100.0	100.0	100.0	95.7
June 29	100	66	98.0	100.0	90.0	92.4
June 30	100	79	100.0	100.0	82.0	96.2
July 6	100	81	99.0	100.0	98.0	93.8
July 7	100	65	99.0	100.0	97.0	93.8

Appendix 4.—Sample size, **survival** 3 d after trials, and survival 7 d after trials of chinook salmon fingerlings in control and treatment groups for **bypass 4** from May to July 1994.

Date	*N*		3-d survival (%)		7-d survival (%)	
	control	treatment	control	treatment	control	treatment
May 26	100	164	100.0	100.0	100.0	100.0
June 1	99	99	100.0	100.0	99.0	99.0
June 2	98	131	100.0	100.0	95.9	98.5
June 8	75	75	100.0	100.0	98.7	92.0
June 9	74	75	100.0	100.0	81.1	48.0
June 14	100	100	98.0	100.0	94.0	99.0
June 16	100	96	99.0	100.0	97.0	96.9
June 21	100	97	97.0	97.9	91.0	97.9
June 22	100	82	99.0	98.9	97.0	92.7
June 27	100	92	100.0	98.8	95.0	87.0
June 28	100	93	98.0	100.0	95.0	100.0
July 1	100	84	100.0	98.8	96.0	94.0
July 5	100	90	99.0	98.9	96.0	94.4
July 11	100	83	99.0	100.0	99.0	97.6
July 12	100	86	100.0	100.0	97.0	96.5

Appendix 5.—**Descaling scores** (mean ± SD) by trial of chinook salmon fingerlings for control, treatment and late-treatment groups for **bypass 1**. Possible score range was from 0 to 36 in increments of 1. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 26	0.0±0.0 (25)	0.5±2.5 (25)	1.4±3.5 (7)
May 31	0.4±1.1 (25)	0.1±0.4 (25)	0.3±0.6 (11)
June 2	0.0±0.2 (25)	0.1±0.3 (25)	0.0±0.0 (2)
June 7	0.0±0.0 (25)	0.4±1.5 (26)	0.3±0.9 (9)
June 9	0.2±0.6 (25)	0.1±0.4 (25)	0.0±0.0 (4)
June 13	0.0±0.0 (25)	0.1±0.4 (25)	0.0±0.0 (4)
June 16	0.3±0.6 (26)	1.2±3.0 (28)	0.1±0.3 (8)
June 20	0.2±0.8 (26)	0.1±0.3 (25)	0.0±0.0 (3)
June 22	0.0±0.2 (25)	0.4±1.0 (25)	0.0±0.0 (2)
June 24	0.3±0.7 (25)	0.2±0.5 (26)	0.0±0.0 (5)
June 28	0.2±1.0 (25)	0.2±0.6 (25)	0.0±0.0 (5)
June 30	0.1±0.3 (25)	0.1±0.3 (25)	0.0±0.0 (3)
July 5	0.2±1.2 (25)	0.1±0.3 (25)	0.0±0.0 (6)
July 7	0.2±1.2 (25)	0.1±0.3 (25)	0.0±0.0 (3)

Appendix 6.—**Descaling scores** (mean ± SD) by trial of chinook salmon fingerlings for control, treatment and late-treatment groups for **bypass 2**. Possible score range was from 0 to 36. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 27	0.5±1.2 (27)	0.2±0.6 (26)	3.0±2.9 (20)
June 1	0.0±0.0 (26)	0.1±0.3 (26)	0.5±1.2 (12)
June 3	0.1±0.4 (25)	0.0±0.0 (25)	0.5±0.8 (10)
June 8	0.2±1.0 (26)	0.1±0.4 (25)	0.9±2.9 (11)
June 10	0.0±0.0 (26)	0.0±0.2 (25)	0.3±0.3 (8)
June 14	0.4±1.3 (25)	0.4±1.2 (25)	2.1±3.4 (7)
June 17	0.1±0.3 (27)	0.3±0.9 (30)	0.0±0.0 (4)
June 21	0.1±0.6 (25)	0.0±0.2 (25)	(0)
June 23	1.2±3.1 (25)	0.2±0.8 (25)	0.0±0.0 (3)
June 27	0.2±0.5 (25)	0.0±0.2 (25)	0.3±0.5 (3)
June 29	0.5±1.6 (26)	0.1±0.3 (25)	0.0±0.0 (3)
July 1	0.0±0.0 (25)	0.0±0.0 (25)	0.0±0.0 (1)
July 6	0.0±0.2 (25)	0.1±0.3 (25)	0.0±0.0 (4)
July 11	0.2±0.5 (25)	0.3±0.5 (25)	0.6±1.2 (5)
July 12	0.1±0.4 (25)	0.4±1.2 (25)	0.0±0.0 (3)

Appendix 7.—**Descaling scores** (mean ± SD) by trial of chinook salmon fingerlings for control, treatment, and treatment groups for **bypass 3**. Possible scores range was from 0 to 36 in increments of 1. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 27	1.0±2.5 (25)	0.0±0.2 (25)	0.9±0.8 (7)
May 31	0.0±0.2 (25)	0.1±0.3 (25)	0.6±0.8 (12)
June 3	0.0±0.2 (25)	0.0±0.2 (25)	2.2±3.9 (5)
June 7	0.0±0.0 (26)	0.0±0.0 (25)	0.7±0.9 (3)
June 10	0.1±0.4 (25)	0.0±0.0 (25)	0.0±0.0 (10)
June 13	0.1±0.4 (25)	0.4±1.6 (25)	0.0±0.0 (7)
June 17	0.3±1.2 (25)	0.1±0.4 (25)	0.1±0.3 (8)
June 20	0.0±0.0 (25)	0.1±0.3 (25)	0.1±0.3 (11)
June 23	1.0±4.7 (25)	0.1±0.4 (25)	0.5±0.5 (4)
June 24	0.1±0.3 (25)	0.0±0.0 (25)	0.0±0.0 (10)
June 29	0.1±0.3 (25)	0.3±1.4 (25)	0.0±0.0 (6)
June 30	0.0±0.2 (25)	0.0±0.0 (25)	0.0±0.0 (7)
July 6	0.1±0.4 (25)	0.0±0.0 (25)	0.0±0.0 (7)
July 7	0.1±0.3 (24)	0.2±0.8 (26)	0.1±0.3 (7)

Appendix 8.—**Descaling scores** (mean ± SD) by trial of chinook salmon fingerlings for control, treatment and late-treatment groups for **bypass 4**. Possible scores range was from 0 to 36 in increments of 1. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 26	0.0±0.0 (25)	0.0±0.0 (25)	0.0±0.0 (2)
June 1	0.0±0.0 (25)	0.0±0.0 (25)	0.4±1.0 (7)
June 2	0.0±0.0 (25)	0.3±0.9 (25)	0.0±0.0 (3)
June 8	0.0±0.0 (25)	0.2±1.0 (25)	(0)
June 9	0.3±1.4 (25)	0.2±0.5 (26)	0.3±0.5 (3)
June 14	0.2±1.0 (25)	0.1±0.3 (25)	0.0±0.0 (6)
June 16	0.1±0.4 (25)	1.7±4.8 (26)	1.3±1.9 (3)
June 21	1.5±3.2 (25)	0.8±1.8 (26)	1.4±3.1 (7)
June 22	0.2±0.8 (27)	0.1±0.4 (25)	0.0±0.0 (4)
June 27	0.2±0.5 (25)	0.0±0.0 (25)	0.0±0.0 (3)
June 28	0.2±0.6 (25)	0.0±0.0 (26)	0.4±0.1 (7)
July 1	0.1±0.3 (25)	0.0±0.0 (26)	0.0±0.0 (8)
July 5	0.0±0.2 (25)	0.1±0.3 (25)	0.0±0.0 (7)
July 11	0.1±0.4 (25)	0.1±0.4 (25)	0.0±0.0 (6)
July 12	0.2±0.8 (25)	0.0±0.0 (25)	0.0±0.0 (3)

Appendix 9.—**Lengths** (mean ± SD; mm) of chinook salmon fingerlings for control, treatment and late-treatment groups by trial for **bypass 1**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 26	82±7 (25)	81±6 (25)	81±7 (7)
May 31	90±5 (25)	87±9 (25)	87±9 (11)
June 2	85±7 (25)	87±8 (25)	94±0 (2)
June 7	86±10 (25)	90±6 (26)	90±6 (9)
June 9	88±6 (25)	91±7 (25)	92±7 (4)
June 13	91±8 (25)	92±6 (25)	86±11 (4)
June 16	96±7 (26)	94±9 (28)	92±10 (8)
June 20	90±10 (26)	92±9 (25)	100±3 (3)
June 22	97±8 (25)	94±9 (25)	100±4 (2)
June 24	98±8 (25)	94±8 (26)	96±7 (5)
June 28	101±12 (25)	96±10 (25)	105±6 (5)
June 30	110±10 (25)	108±11 (25)	111±7 (3)
July 5	101±13 (25)	103±12 (25)	99±5 (6)
July 7	103±10 (25)	101±12 (25)	98±5 (3)

Appendix 10.—**Lengths** (mean ± SD; mm) of chinook salmon fingerlings for control, treatment and late-treatment groups by trial for **bypass 2**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 27	89±6 (27)	84±8 (26)	88±5 (19)
June 1	86±6 (26)	86±7 (26)	87±5 (12)
June 3	88±6 (25)	86±10 (25)	89±5 (10)
June 8	90±8 (26)	91±6 (25)	87±9 (11)
June 10	87±8 (26)	91±6 (25)	91±7 (13)
June 14	93±7 (25)	90±10 (25)	94±6 (7)
June 17	95±8 (27)	93±9 (30)	89±10 (4)
June 21	93±10 (25)	91±11 (25)	(0)
June 23	94±10 (25)	93±6 (25)	97±6 (3)
June 27	96±11 (25)	94±12 (25)	100±4 (3)
June 29	100±8 (26)	105±13 (25)	109±5 (3)
July 1	100±12 (25)	99±10 (25)	89±0 (1)
July 6	102±9 (25)	102±7 (25)	98±13 (4)
July 11	111±8 (25)	106±7 (25)	107±13 (5)
July 12	104±11 (25)	107±10 (25)	107±0 (3)

Appendix 11.—**Lengths** (mean ± SD; mm) of chinook salmon fingerlings for control, treatment and late-treatment groups by trial for **bypass 3**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 27	86±6 (25)	87±5 (25)	90±5 (7)
May 31	88±7 (12)	87±8 (25)	91±4 (12)
June 3	88±7 (25)	86±7 (25)	87±7 (5)
June 7	93±5 (26)	91±5 (25)	91±3 (3)
June 10	89±10 (25)	90±7 (25)	88±6 (11)
June 13	90±7 (25)	91±8 (25)	90±9 (7)
June 17	93±8 (25)	95±8 (25)	94±10 (8)
June 20	90±9 (25)	91±10 (25)	95±8 (11)
June 23	95±11 (25)	95±7 (25)	99±6 (4)
June 24	97±8 (25)	98±10 (25)	96±7 (10)
June 29	97±12 (25)	98±12 (25)	100±6 (6)
June 30	107±15 (25)	110±11 (25)	111±14 (7)
July 6	101±9 (25)	103±10 (25)	104±10 (7)
July 7	103±11 (24)	104±8 (26)	102±13 (7)

Appendix 12.—**Lengths** (mean ± SD; mm) of chinook salmon fingerlings for control, treatment, and late-treatment groups by trial for **bypass 4**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 26	79±8 (25)	81±9 (25)	71±8 (2)
June 1	85±9 (25)	90±6 (25)	88±8 (7)
June 2	85±7 (25)	85±7 (25)	88±4 (3)
June 8	90±7 (25)	86±11 (25)	(0)
June 9	91±6 (25)	87±7 (26)	87±4 (3)
June 14	89±11 (25)	97±6 (25)	98±4 (6)
June 16	97±6 (25)	93±10 (26)	86±12 (3)
June 21	93±10 (25)	94±7 (26)	97±6 (7)
June 22	94±11 (27)	94±12 (25)	94±12 (4)
June 27	96±9 (25)	90±12 (25)	100±5 (3)
June 28	94±10 (25)	102±8 (26)	93±9 (7)
July 1	100±11 (25)	102±8 (26)	96±9 (8)
July 5	103±9 (25)	105±12 (25)	98±16 (7)
July 11	108±8 (25)	105±12 (25)	104±13 (6)
July 12	108±9 (25)	105±9 (25)	99±10 (3)

Appendix 13.—**Weights** (mean ± SD; g) of chinook salmon fingerlings for control, treatment and late-treatment groups by trial for **bypass 1**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 26	6.7±1.9 (25)	6.5±1.4 (25)	6.6±1.7 (7)
May 31	7.7±1.5 (25)	7.1±1.9 (25)	7.0±1.8 (11)
June 2	6.9±1.7 (25)	7.2±1.8 (25)	9.0±0.0 (2)
June 7	8.1±2.8 (25)	8.5±1.8 (26)	8.6±1.9 (9)
June 9	8.2±2.0 (25)	8.9±2.1 (25)	9.5±1.7 (4)
June 13	9.1±2.5 (25)	9.3±1.8 (25)	8.0±2.6 (4)
June 16	10.2±2.1 (26)	10.1±2.7 (28)	9.0±2.7 (8)
June 20	9.0±3.1 (26)	9.6±2.7 (25)	12.5±0.9 (3)
June 22	11.3±2.8 (25)	10.2±2.7 (25)	12.7±1.2 (2)
June 24	11.5±2.8 (25)	10.4±2.7 (26)	10.9±2.5 (5)
June 28	12.8±4.0 (25)	10.9±3.2 (25)	14.7±2.5 (5)
June 30	13.8±3.4 (25)	12.3±3.5 (25)	13.0±3.2 (3)
July 5	13.5±4.5 (25)	14.6±4.8 (25)	12.6±2.0 (6)
July 7	12.9±3.5 (25)	12.4±4.0 (25)	10.8±1.4 (3)

Appendix 14.—**Weights** (mean ± SD; g) of chinook salmon fingerlings for control, treatment and late-treatment groups by trial for **bypass 2**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 27	7.4±2.4 (27)	6.2±1.7 (26)	7.2±1.3 (20)
June 1	6.9±1.5 (26)	7.1±1.7 (26)	7.0±1.3 (12)
June 3	7.1±1.5 (25)	6.7±2.1 (25)	7.4±1.4 (10)
June 8	8.8±2.4 (26)	8.9±1.6 (25)	8.1±2.3 (11)
June 10	8.4±2.1 (26)	9.4±2.0 (25)	10.6±1.8 (8)
June 14	9.9±2.2 (25)	8.7±2.6 (25)	9.9±1.8 (7)
June 17	10.2±2.5 (27)	9.5±2.8 (30)	8.8±3.4 (4)
June 21	10.6±2.8 (25)	9.5±3.1 (25)	(0)
June 23	10.3±3.0 (25)	9.8±2.1 (25)	11.5±2.3 (3)
June 27	11.0±3.6 (25)	10.4±3.7 (25)	12.6±2.3 (3)
June 29	12.4±2.8 (26)	11.5±3.9 (25)	13.1±2.2 (3)
July 1	12.9±4.4 (25)	12.3±3.4 (25)	9.2±0.0 (1)
July 6	14.0±3.5 (25)	13.3±2.7 (25)	12.4±4.6 (4)
July 11	16.5±3.6 (25)	15.7±3.4 (25)	15.9±4.6 (5)
July 12	14.2±4.4 (25)	18.9±14.7 (25)	15.2±1.3 (3)

Appendix 15.—**Weights** (mean ± SD; g) of chinook salmon fingerlings for control, treatment and late-treatment groups by trial for **bypass 3**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 27	6.7±1.3 (25)	6.7±1.3 (25)	7.5±1.3 (7)
May 31	7.2±1.9 (12)	7.2±2.0 (25)	7.9±1.0 (12)
June 3	7.1±1.9 (25)	6.7±1.7 (25)	7.0±1.9 (5)
June 7	9.7±1.8 (26)	8.7±1.5 (25)	9.3±1.2 (3)
June 10	9.0±2.5 (25)	8.9±2.1 (25)	9.0±2.0 (11)
June 13	8.8±2.0 (25)	8.8±2.6 (25)	9.3±2.8 (7)
June 17	9.7±2.6 (25)	10.3±2.3 (25)	10.5±3.5 (8)
June 20	8.8±2.5 (25)	9.1±2.7 (25)	9.3±1.8 (10)
June 23	10.0±3.1 (25)	10.3±2.3 (25)	10.7±1.4 (4)
June 24	11.9±2.7 (25)	12.1±3.0 (25)	11.4±2.1 (10)
June 29	12.1±3.7 (25)	12.2±3.8 (25)	12.7±2.2 (6)
June 30	12.0±4.2 (25)	12.7±3.5 (25)	14.5±4.0 (7)
July 6	13.1±3.2 (25)	14.0±3.7 (25)	15.1±3.6 (7)
July 7	13.3±4.5 (24)	14.2±3.8 (26)	13.2±4.9 (7)

Appendix 16.—**Weights** (mean ± SD; g) of chinook salmon fingerlings for control, treatment and late-treatment groups by trial for **bypass 4**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 26	5.8±1.6 (25)	6.5±2.0 (25)	4.1±1.6 (2)
June 1	6.6±1.9 (25)	7.8±2.0 (25)	7.5±1.9 (7)
June 2	6.9±1.7 (25)	6.7±1.6 (25)	7.8±1.6 (3)
June 8	8.3±2.0 (25)	7.4±2.6 (25)	(0)
June 9	8.8±1.8 (25)	7.7±1.7 (26)	8.3±1.1 (3)
June 14	8.7±2.7 (25)	10.6±2.0 (25)	11.9±1.2 (6)
June 16	10.8±2.1 (25)	9.9±2.8 (26)	8.6±3.1 (3)
June 21	10.6±3.1 (25)	10.3±2.4 (26)	12.1±2.2 (7)
June 22	10.0±3.3 (27)	10.2±3.8 (25)	10.7±4.1 (4)
June 27	11.4±2.7 (25)	9.0±3.3 (25)	12.5±1.9 (3)
June 28	10.1±3.1 (25)	13.2±2.9 (26)	10.9±2.8 (7)
July 1	12.1±3.7 (25)	16.2±16.4 (26)	12.0±3.2 (8)
July 5	13.8±3.5 (25)	15.0±4.2 (25)	12.8±5.9 (7)
July 11	17.9±14.6 (25)	15.5±4.9 (25)	14.8±4.9 (6)
July 12	16.4±4.0 (25)	15.5±3.6 (25)	13.5±4.3 (3)

Appendix 17.—**Injured** (%) chinook salmon fingerlings in control, treatment and late-treatment groups for **bypass 1**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 26	0.0 (25)	0.0 (25)	0.0 (7)
May 31	0.0 (25)	0.0 (25)	0.0 (11)
June 2	0.0 (25)	0.0 (25)	0.0 (2)
June 7	0.0 (25)	0.0 (26)	0.0 (9)
June 9	0.0 (25)	0.0 (25)	0.0 (4)
June 13	0.0 (25)	0.0 (25)	0.0 (4)
June 16	16.0 (26)	0.0 (28)	25.0 (8)
June 20	0.0 (26)	0.0 (25)	0.0 (3)
June 22	0.0 (25)	0.0 (25)	0.0 (2)
June 24	0.0 (25)	0.0 (26)	0.0 (5)
June 28	8.0 (25)	0.0 (25)	0.0 (5)
June 30	0.0 (25)	4.0 (25)	0.0 (3)
July 5	0.0 (25)	0.0 (25)	0.0 (6)
July 7	12.0 (25)	4.0 (25)	0.0 (3)

Appendix 18.—**Injured** (%) chinook salmon fingerlings in control, treatment and late-treatment groups by trial for **bypass 2**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 27	0.0 (27)	7.7 (26)	5.0 (20)
June 1	0.0 (26)	0.0 (26)	16.7 (12)
June 3	0.0 (25)	8.0 (25)	0.0 (10)
June 8	0..0 (26)	4.0 (25)	0.0 (11)
June 10	0.0 (26)	0.0 (25)	0.0 (8)
June 14	12.0 (25)	4.0 (25)	0.0 (7)
June 17	0.0 (27)	6.7 (30)	25.0 (4)
June 21	0.0 (25)	0.0 (25)	
June 23	4.0 (25)	4.0 (25)	0.0 (3)
June 27	0.0 (25)	0.0 (25)	33.3 (3)
June 29	0.0 (26)	0.0 (25)	0.0 (3)
July 1	0.0 (25)	0.0 (25)	0.0 (1)
July 6	0.0 (25)	12.0 (25)	0.0 (4)
July 11	0.0 (25)	16.0 (25)	0.0 (5)
July 12	8.0 (25)	0.0 (25)	0.0 (3)

Appendix 19.—**Injured** (%) chinook salmon fingerlings in control, treatment and late-treatment groups by trial for **bypass 3**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 27	4.0 (25)	0.0 (25)	42.9 (7)
May 31	0.0 (25)	0.0 (25)	0.0 (12)
June 3	8.0 (25)	8.0 (25)	0.0 (5)
June 7	0.0 (26)	0.0 (25)	0.0 (3)
June 10	0.0 (25)	0.0 (25)	0.0 (10)
June 13	0.0 (25)	4.0 (25)	0.0 (7)
June 17	0.0 (25)	16.0 (25)	0.0 (8)
June 20	0.0 (25)	4.0 (25)	0.0 (11)
June 23	4.0 (25)	0.0 (25)	0.0 (4)
June 24	0.0 (25)	0.0 (25)	0.0 (10)
June 29	0.0 (25)	0.0 (25)	0.0 (6)
June 30	0.0 (25)	0.0 (25)	0.0 (7)
July 6	4.0 (25)	4.0 (25)	0.0 (7)
July 7	8.3 (24)	3.8 (26)	0.0 (7)

Appendix 20.—**Injured** (%) chinook salmon fingerlings in control, treatment and late-treatment groups by trial for **bypass 4**. Sample sizes are in parentheses.

Date	Control	Treatment	Late treatment
May 26	0.0 (25)	0.0 (25)	0.0 (2)
June 1	0.0 (25)	0.0 (25)	14.3 (7)
June 2	0.0 (25)	0.0 (25)	0.0 (3)
June 8	0.0 (25)	8.0 (25)	
June 9	0.0 (25)	0.0 (26)	0.0 (3)
June 14	4.0 (25)	0.0 (25)	0.0 (6)
June 16	4.0 (25)	26.9 (26)	0.0 (3)
June 21	0.0 (25)	7.7 (26)	0.0 (7)
June 22	3.7 (27)	4.0 (25)	0.0 (4)
June 27	4.0 (25)	0.0 (25)	0.0 (3)
June 28	4.0 (25)	0.0 (26)	0.0 (7)
July 1	0.0 (25)	0.0 (26)	0.0 (8)
July 5	0.0 (25)	4.0 (25)	14.3 (7)
July 11	4.0 (25)	4.0 (25)	0.0 (6)
July 12	4.0 (25)	0.0 (25)	0.0 (3)

Appendix 21.—Flow (m^3/s) at bypass entrance (A), flow at adjacent bypass entrance (B), fishing effort (eff; min), percent fish recaptured (rec), weight (mean ± SD; g) and fork length (mean ± SD; mm) of fish recaptured 8 min or less after introduction (early), and weight and fork length of fish recaptured more than 8 min after introduction (late) by bypass for 12 trials of 80 chinook salmon fingerlings introduced into bypass entrances. Sample sizes are in parentheses. Significant differences between early and late salmon weight and length are marked with an asterisk (ANOVA; $P<0.05$).

Flow				Weight		Fork length	
A	B	Eff	Rec	Early	Late	Early	Late
				Bypass 1			
2.26	2.15	100	91.3	5.3±1.0 (50)	5.1±1.5 (23)	80±5 (50)	79±8 (23)
2.26	2.15	74	88.8	4.8±1.4 (64)	5.0±1.9 (7)	77±8 (64)	78±9 (7)
2.26	2.21	106	97.5	5.1±1.1 (69)	5.2±1.2 (9)	77±6 (69)	76±5 (9)
2.26	2.21	90	93.8	4.8±1.3 (68)	5.3±1.9 (7)	75±8 (68)	77±12 (7)
				Bypass 2			
2.15	2.26	111	63.8	5.6±1.2 (24)	5.1±1.1 (27)	80±5 (24)	79±5 (27)
2.15	2.26	86	73.8	5.2±1.4 (29)	5.2±1.2 (30)	80±8 (29)	79±6 (30)
2.21	2.26	114	91.3	5.0±1.2 (48)	5.1±1.1 (25)	78±6 (48)	77±5 (25)
2.21	2.26	98	82.5	4.9±1.1 (35)	5.4±1.3 (31)	77±6 (35)	79±6 (31)
				Bypass 3			
1.87	1.92	122	96.3	5.2±1.5 (59)	5.9±0.8 (18)	77±7 (59)*	81±4 (18)*
1.87	1.92	100	100.0	5.1±1.2 (63)	5.4±1.3 (17)	77±6 (63)	79±6 (17)
				Bypass 4			
1.92	1.87	110	97.5	5.5±1.3 (75)	5.2±0.6 (3)	79±6 (75)	79±5 (3)
1.92	1.87	90	96.3	5.9±1.6 (71)	5.7±1.4 (6)	80±7 (71)	79±8 (6)

Appendix 22.—Number of treatment salmon observed in gate chambers by date of observation, time (min) of observation after treatment group introduction(s), location of introduction (Byp), bypass entrance flow (m^3/s), and gate structure chamber (gate chamber) turbulence (T). Water entering bypasses 1 and 2 remains separate from water entering bypasses 3 and 4. Water entering bypasses 1 and 2 and water entering bypasses 3 and 4 mix in separate chambers in the gate structure.

	Time after introduction				Bypass entrance flow				Gate chamber turbulence				Observed salmon per gate chamber	
Date	Byp	Time	Byp	Time	1	2	3	4	1	2	3	4	1&2	3&4
6/24	-	-	3	63	2.55	2.35	2.12	2.01	T	T	-	-	0	2
6/27	-	-	4	60	2.41	2.43	2.04	2.07	T	T	-	-	0	4
6/28	1	69	4	179	2.35	2.40	1.95	2.09	T	T	-	-	3	0
6/29	-	-	1	63	2.49	2.37	2.12	2.12	-	-	-	-	0	0
6/30	1	32	-	-	2.38	2.35	1.98	2.07	-	-	-	-	1	0
7/1	1	37	-	-	2.29	2.36	1.84	1.98	T	T	-	-	1	0
7/5	-	-	1	40	2.35	2.38	1.92	2.01	T	-	-	-	0	0
7/6	1	93	-	-	2.24	2.17	1.67	1.92	-	T	-	-	4	0
7/7	-	-	1	33	-	-	-	-	-	-	-	-	0	1
7/11	1	139	4	48	2.24	2.01	1.81	1.84	-	-	-	-	0	0
7/12	1	36	4	118	1.87	2.32	1.92	1.87	T	T	-	-	5	0